Study of the processing of pearl millet (*Pennisetum glaucum*) into *ben-saalga*, a fermented gruel from Burkina Faso

Guyot[1*] Jean-Pierre, Mouquet[1,2] Claire, Tou[1,2] El Hassane, Counil[1] Emilie, Traore[2] Alfred S, Trèche[1] Serge

[1] UR106 "Nutrition, Alimentation, Sociétés", IRD, BP 64501, 34394 Montpellier cedex 5, France
[2] CRSBAN/UFR-SVT/Univ. de Ouagadougou, 03 BP 7021, Ouagadougou, Burkina Faso.

*Corresponding author: *jpguyot@mpl.ird.fr*

- Abstract -

Ben-saalga is a Burkinabè fermented gruel which is widely consumed by young children. Preliminary results obtained from surveys performed in producing units at Ouagadougou (Burkina Faso) on the processing of pearl millet (*Pennisetum glaucum*) into *ben-saalga* are presented. Briefly, the processing consists of the following steps: washing of the grains (optional), soaking, grinding, wet sieving of the resulting dough, settling and cooking. The processing is characterised by the large amount of water used relative to the initial amount of raw material and by the duration of the soaking and the settling being the longer steps (16h and 11h, respectively). During the soaking and the settling the pH decreased, the final pH being lower during the settling. The soaking step is mainly characterized by an alcoholic fermentation, whereas the settling step is dominated by a lactic acid fermentation. A strong decrease in the content of antinutritional factors, such as phytates and raffinose, was observed throughout the processing, but the resulting gruel had a very low dry matter content. Investigations are under progress to improve the energy density and the lipid and protein content of *ben-saalga*.

Key words: *Ben-saalga* – Millet – Fermentation – Processing – Lactic acid.

- Résumé -

Etude de la transformation du mil (*Pennisetum glaucum*) en *ben-saalga*, une bouillie fermentée traditionnelle du Burkina Faso

Le *ben-saalga* est une bouillie burkinabè traditionnelle obtenue par cuisson d'une suspension diluée de pâte fermentée de mil. Des enquêtes réalisées à Ouagadougou ont montré qu'elle était largement consommée par les jeunes enfants. Nous présentons ici la description du procédé traditionnel de transformation du mil en *ben-saalga* et les principales modifications chimiques qui l'accompagnent. Les résultats présentés sont obtenus à partir d'enquêtes et de prélèvements réalisés auprès de 24 unités de production. Les teneurs en phytates (IP6), mono- et diholosides ont été déterminées par HPIC, celles en lactate, acétate et éthanol par HPLC.

Les différentes étapes consistent successivement en un lavage des grains, un trempage, l'ajout d'ingrédients (e.g. gingembre, menthe, poivre noir), un broyage, un tamisage de la pâte obtenue, une décantation et une cuisson finale. Les principales caractéristiques sont (s: écart-type):

- l'importante consommation d'eau (moyenne = 80 l; s = 12) pour une quantité moyenne initiale de matière première de 6,6 kg (s = 3,9);
- la durée du trempage et de la décantation qui sont respectivement de 16 h (s = 7; min 6, max 31) et de 11 h (s = 4; min 2, max 20);
- la très faible teneur en matière sèche (MS) de la bouillie avant addition de sucre (7,3 g/100g) correspondant à une densité énergétique d'environ 30 kcal/100g.

Le pH en fin de décantation (moyenne = 3,7; s = 0,1) est inférieur à celui en fin de trempage (moyenne = 4,4; s = 0,1). Le trempage est caractérisé par une production d'éthanol supérieure à celle d'acide lactique, alors que l'étape de décantation est dominée par une fermentation lactique. Les autres modifications chimiques du mil au cours du procédé se caractérisent par une diminution des teneurs en saccharose et en raffinose, alors qu'il est observé une augmentation transitoire des teneurs en glucose et en fructose. La teneur en phytates (IP6) varie de 0,67g MS (s = 0,05) dans les grains lavés à 0,18 g/100g MS (s = 0,12) dans la pâte fermentée, avec le taux de diminution le plus important (65%) observé lors de la décantation. La teneur en protéines diminue de 10,2 g/100g MS (s = 0.6) dans la graine à 6,0 g/100g MS (s = 2,1) dans la pâte fermentée, ce qui s'explique par l'élimination de fractions riches en protéines lors du tamisage.

Pour améliorer la qualité nutritionnelle du *ben-saalga* en vue de son utilisation par les jeunes enfants, la densité énergétique peut-être augmentée par ajout d'une source d'α-amylase (malt, enzymes commerciales) et les teneurs en protéines et en lipides améliorées par co-fermentation avec des légumineuses. Une telle approche se justifie aussi par la possibilité de réduire naturellement les teneurs en phytates et α-galactosides.

Mots-clés: *Ben-saalga* – Mil – Fermentation – Transformation – Acide lactique.

INTRODUCTION

Although a great deal of information is available on numerous traditional cereal and cassava-based fermented foods[1], many descriptions do not rely on a statistically sound approach, and are most often based on the description of only one (or a very few) traditional producing units. Some reasons of this difficulty to obtain information which attempt to describe as best as possible the reality are due to the fact that such studies, considering the surveys, the sampling and the processing of numerous samples of material, are heavy to perform, time consuming and expensive. In addition, there is not always an easy access to these traditional producing units, which often are cottage or family (micro)-enterprises, thus results obtained can be very frustrating when balanced against the amount of work to get it.

When attempts are made to give a more extensive description based on relatively high number of processing (producing) units, with intention to produce reliable data, often previous estimates on the existing number of units in a determined place are lacking, which prevents to randomise the producing units to be investigated and which could introduce bias. Thus there is no clear vision of the true variability of the different processes applied in terms of duration and mass balance. Furthermore, there is also a lack of information on the extent of the variability of the physico-chemical characteristics of the resulting foodstuffs. This could impair any strategy (i) to improve the existing processes if the expectations of the producers and consumers are to be taken into account, and (ii) to establish standards if a more reliable quality of foodstuffs is expected. Sustainability in quality must be developed through the implementation of reliable approaches in order to properly address two major challenges:

- to feed the urban population with good nutritional and sanitary quality products;
- to sustain the commercial exchanges between countries: importation and exportation requires quality criteria.

Taking into account these points, i.e. difficulties and expected outcomes, the processing of pearl millet (*Pennisetum glaucum)* into *ben-saalga*, a traditional Burkinabè gruel obtained by cooking a diluted fermented paste of pearl millet is being studied in the frame of an European research project (the “Cerefer” project), with the objective to elaborate ways to improve its nutritional and sanitary quality.

The particular interest for millet based fermented gruels (*ben-saalga* and its derived foodstuff: *ben-kida*) is based on results from previous surveys performed in Ouagadougou in 1999 in 70 representative producing units[2]. This study allowed estimating that 49% of households consume these fermented gruels. Among the households considered as regular consumers, it was shown that 75% of children less than 5 years old consume regularly millet-based fermented gruels, whereas only few adults (19%) are consumers, justifying an increased interest for this traditional gruel as a complementary food for young children. It must also be emphasized that the same surveys showed that these gruels are produced only by women, which in majority are Muslim (92%) and belong to the *Mossi* ethnic group (73%). Another interesting point was that the passing down of the traditional knowledge is made by a direct ascendant (mother) in 31% of the cases or by another member of the family in 34% of the cases.

As preliminary results, we report here on the description of the traditional processing of pearl millet into *ben-saalga* and on main chemical changes occurring during the process. The choice of focusing more specifically the study on the gruel *ben-saalga* is justified by the fact that the corresponding processing diagram is also part of the processing diagram of *ben-kida.*

MATERIAL AND METHODS

Observations and sampling in producing units

24 producing units of fermented gruels (*ben-saalga* and *ben-kida)* have been randomly selected from a list of 93 units identified one year before (1999) during a preliminary survey on the production, commercialisation and consumption of *ben-saalga* in Ouagadougou[2].

To describe the different steps of the processing and characterise the variability of the resulting product, the following measurements were performed in the producing units: duration of each step; weighing of raw material used (grains, other ingredients, water), intermediary products, waste and final products; measurement of pH. Samples of product at the different stages were taken and freeze-dried for further analysis.

Fermentation kinetics

Since producing units were at the family scale, access to the different stages of the processing was not always easy, mainly for operations occurring overnight, which illustrates the limit of the approach as indicated in the introduction. Thus fermentation kinetics during soaking and settling were investigated by reproducing field conditions based on survey data and described here (tables 1 and 2). Experiments were performed at the University of Ouagadougou at ambient temperature, using identical recipients to those used by the producers. For soaking, five independent pilot scale experiments were performed. For settling, three series of independent triplicate experiments were performed. Grains for the soaking experiment and non fermented paste for the decantation experiment were bought from 3 different producers.

Analytical methods

Phytate (IP6) content was determined on freeze-dried samples by HPIC using an Omnipac Pax-100 anion-exchange column[3].

Lactic acid, acetate, ethanol in supernatants from the soaking and settling steps were analysed by HPLC using an Aminex HPX-87H column, and mono- and disaccharides were analysed by HPIC using a Carbopac PA1 column[4].

Crude protein (Nx6.25) was determined by the Kjeldahl's method.

Table 1: Amount of material and water used at the different steps of processing to prepare *ben-saalga*.

	Mean	sd*	Median	Min	Max
pearl millet (kg)	6.6	3.9	5.9	1.8	18.1
water for washing (l)	12.5	10.5	10.3	0.0	39.2
water for soaking (l)	8.9	4.2	8.8	3.3	15.3
ground millet (kg)	10.5	4.6	10.8	4	17.1
water for grinding (l)	5.7	4.9	5.0	0.0	20.3
wet dough (kg)	12.8	7.7	10.9	1.9	32.3
water for sieving (l)	39.3	22.7	31.8	9.9	106.9
Supernatant of the sieving step used for cooking (l)	23.9	11.1	24.3	5.1	46.8
fermented paste used for cooking (kg)	9.1	3.8	9.7	2.6	15.3
water added during cooking (l)	13.4	9.8	13.3	0.0	31.7

**standard deviation.*

Table 2: Duration of the different steps during the traditional processing of pearl millet into *ben-saalga*.

	Duration			
	Mean	sd*	Median	Min-Max
Washing before soaking (min)	10	7	6	2-25
soaking (h)	16	7	16	6-31
Washing after soaking (min)	11	9	8	2-40
Grinding (including time to go to the milling unit) (min)	50	39	38	13-190
sieving (min)	23	14	18	5-60
settling (h)	11	4	10	2-20
cooking of the fermented paste (min)	11	11	6	1-40

**standard deviation.*

RESULTS AND DISCUSSION

Description of pearl millet processing into *ben-saalga*

From measurements performed at the producing units, the successive following steps were determined (figure 1): washing of the grains (optional), soaking, washing, wet grinding (pepper, ginger, mint, aniseed can be added at this step), sieving, settling of the paste resulting from sieving and cooking. This diagram is similar to other processing of cereals starting with a soaking step (e.g. *ogi*, *mawè, poto-poto*). Amount of material and water used to produce *ben-saalga* and durations and pH at the different steps are indicated in Table 1 and 2, respectively. It has to be emphasized that the processing requires large volumes of water (mean = 80 l, s = 12 l) compared to the initial amount of raw material (mean = 6.6 kg, s = 3.9 kg), the sieving being the most consuming step with the use of 39.3 l (s = 22.7 l). The soaking and the settling are the longer steps (table 1). During the soaking the pH decreases from an average initial value of 6.6 (s = 0.1) to an average final value of 4.4 (s = 0.1) and during the settling the pH decreases from 5.5 (s = 0.2) to 3.7 (s = 0.1), suggesting that a fermentation occurs during these steps (table 2). At the end of processing, the gruel is characterised by a very low dry matter content (7.3 g/100g, s = 2.3 g/100g, n = 4) corresponding to an energy density of about 125 kJ (30 kcal)/100g of gruel.

From table 3, it can be seen that the major changes observed in the chemical composition of pearl millet during processing are:

- a decrease in the phytate (IP6) content throughout the processing with the highest reduction (65%) during settling;
- a strong lowering of the sucrose and raffinose contents, whereas fructose and glucose transiently increased between soaking and grinding;
- a decrease in the crude protein content from 10.2 g/100g DM in the grains to 6.0 g/100g DM in the fermented paste. This decrease is due to the elimination of some protein rich fractions at the sieving step.

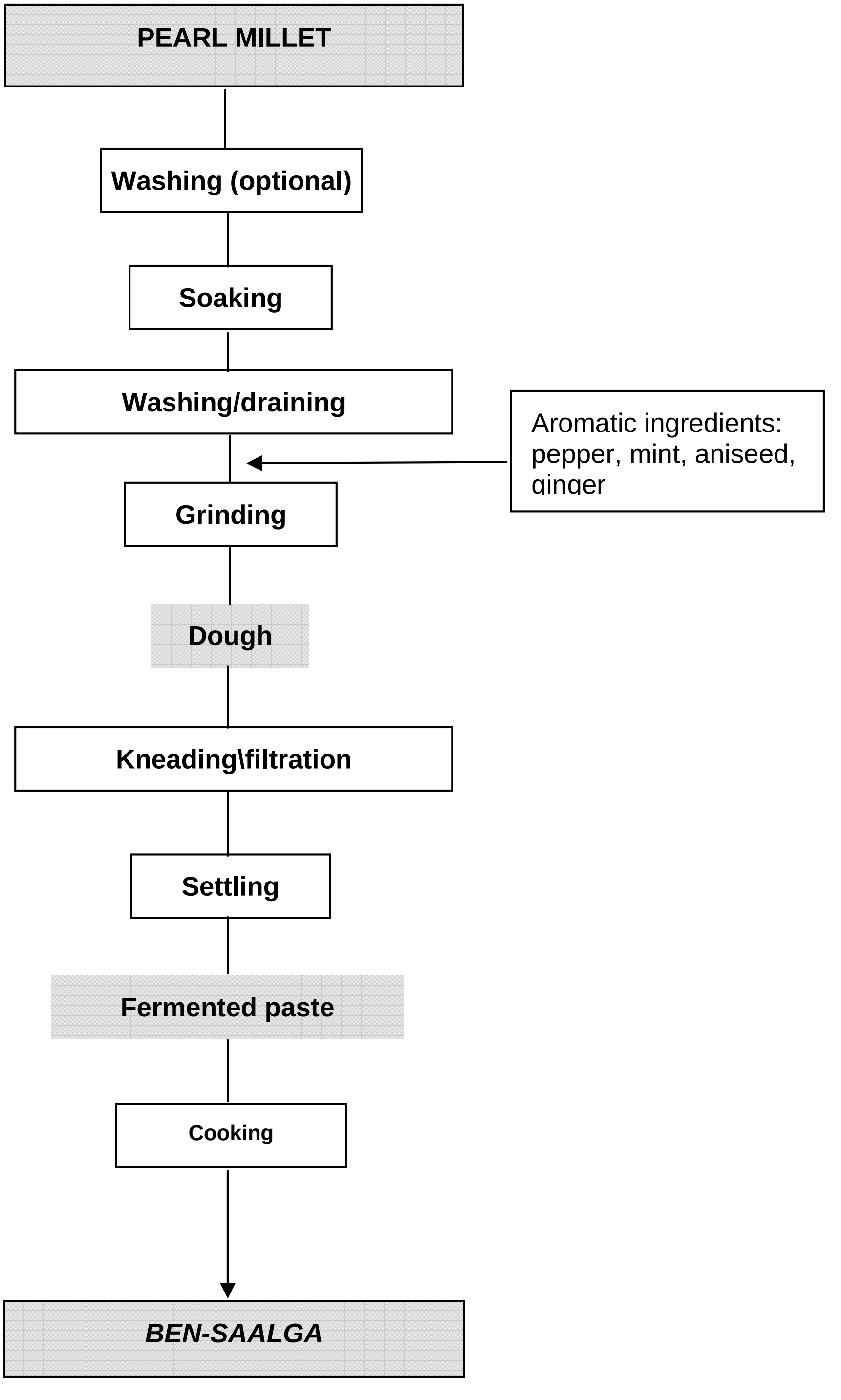

Figure 1: Traditional processing of pearl millet into *ben-saalga*.

Table 3: Main chemical changes occurring during the processing of pearl millet into *ben-saalga (results are average values in g/100g DM with standard deviation in brackets).*

	Proteins	Phytate (IP6)	Glucose	Fructose	Sucrose	Raffinose
washed grains	10.2 (0.6)	0.67 (0.05)	0.12 (0.08)	0.08 (0.07)	1.09 (0.33)	0.48 (0.23)
soaked grains	10.1 (0.6)	0.63 (0.10)	0.30 (0.20)	0.10 (0.09)	0.27 (0.17)	0.21 (0.16)
non fermented paste	8.7 (1.2)	0.51 (0.13)	1.36 (0.56)	0.31 (0.20)	0.03 (0.02)	0.04 (0.05)
fermented paste	6.0 (2.1)	0.18 (0.12)	0.23 (0.59)	0.05 (0.05)	0.01 (0.01)	0.08 (0.27)

Fermentation kinetics

Decrease of pH during soaking and settling led to investigate the kinetics of product formation in order to better characterize these steps.

Surprisingly, the soaking step is characterised by a higher production of ethanol than lactic acid (figure 2A). In contrast, as expected from the low final pH observed, the decantation step is dominated by lactic acid fermentation (figure 2B). Production of ethanol is also observed with traces of acetate. It has to be emphasized that lactic acid formation showed a large variability as indicated by standard deviations (figure 2B), whereas ethanol and acetate concentrations did not vary so much. Variability in lactic acid production demonstrates the need to establish conditions allowing controlling the process and reducing the extent of variability. Such a control would be important to produce gruels with more defined characteristics.

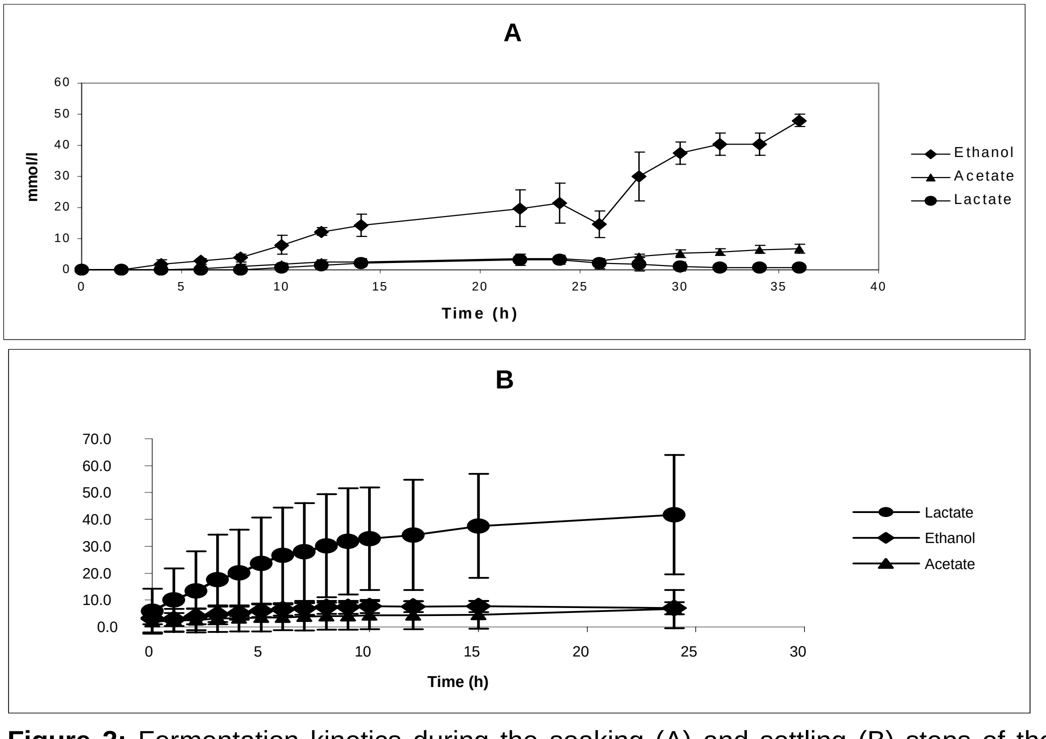

Figure 2: Fermentation kinetics during the soaking (A) and settling (B) steps of the processing of pearl millet into *ben-saalga* (Y-axis in mmol/l; bars are standard deviations).

Samples taken in different producing units at the soaking and settling steps are being analysed in order to establish comparisons between the experimental data and field data.

CONCLUSION

Processing of pearl millet into *ben-saalga* involves two fermentation steps: soaking and settling. Whereas the soaking step seems dominated by an alcoholic fermentation, fermentation kinetics experiments show that a lactic acid fermentation occurs during the settling step, contributing to impart some natural protection against food-borne pathogens.

Levels of antinutritional factors, such as phytates and raffinose are naturally decreased during fermentation. However, considering the low energy density and protein content of *ben-saalga*, additional improvements are necessary to produce complementary foods with appropriate characteristics. Energy density can be increased by adding α-amylase sources (e.g. malt); lipid and protein content can be improved by co-fermentation with beans and pulses.

REFERENCES

1. Steinkraus KH. Handbook of indigenous fermented foods. New York: Marcel Dekker, 1995:211-64.
2. Djossou VA. Etude de la production, de la commercialisation et de la consommation des bouillies à base de petit mil fermenté à Ouagadougou, Burkina Faso. Mémoire de DESS Industries Agro-Alimentaires. Ouagadougou: Université de Ouagadougou, 2000.
3. Talamond P, Doulbeau S, Rochette I, Guyot JP, Trèche S. Anion-exchange high-performance liquid chromatography with conductivity detection for the analysis of phytic acid in food. J Chromatogr A 2000;871:7-12.
4. Calderon M, Loiseau G, Guyot JP. Nutritional requirements and simplified cultivation medium to study growth and energetics of a sourdough lactic acid bacterium *Lactobacillus fermentum* Ogi E1 during heterolactic fermentation of starch. J Appl Microbiol 2001;90:508-16.

Acknowledgments: *This work was funded by the European Commission contract N° ICA4-CT-2002-10047 (www.mpl.ird.fr/cerefer/).*